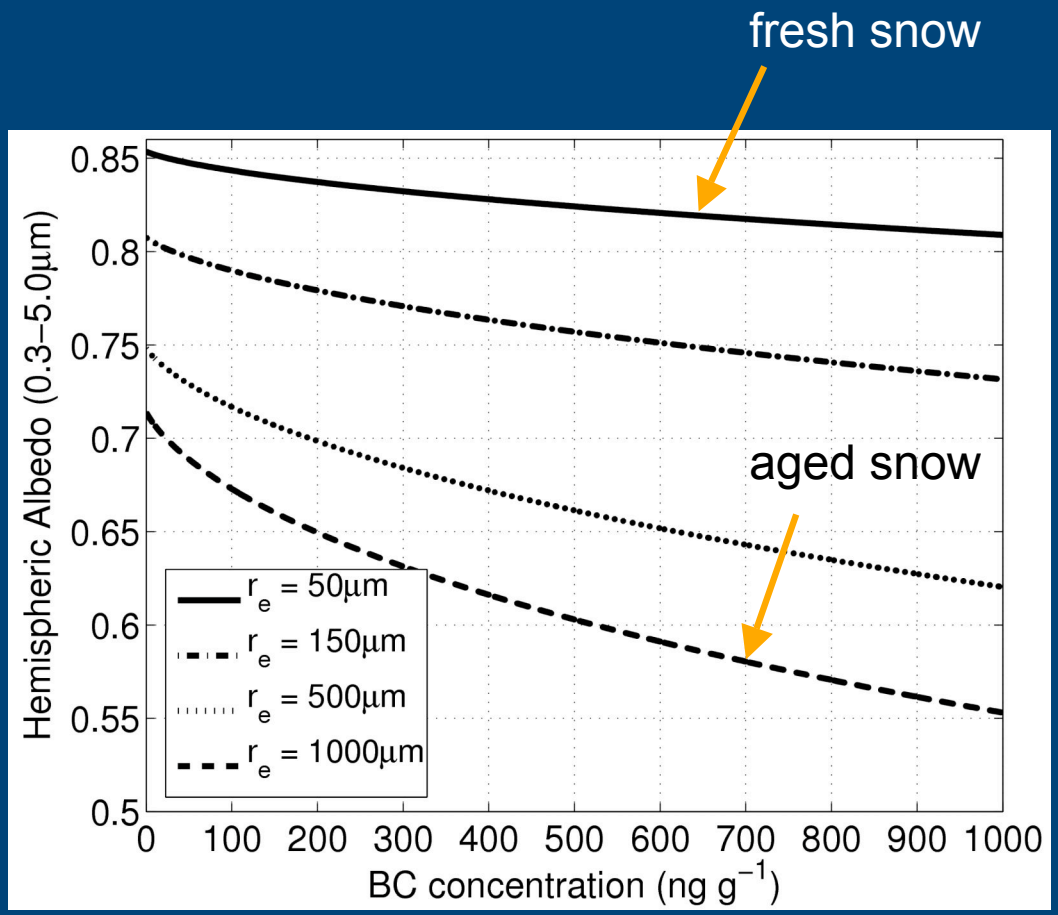
Modeling Climate Effects of Black Carbon in Snow

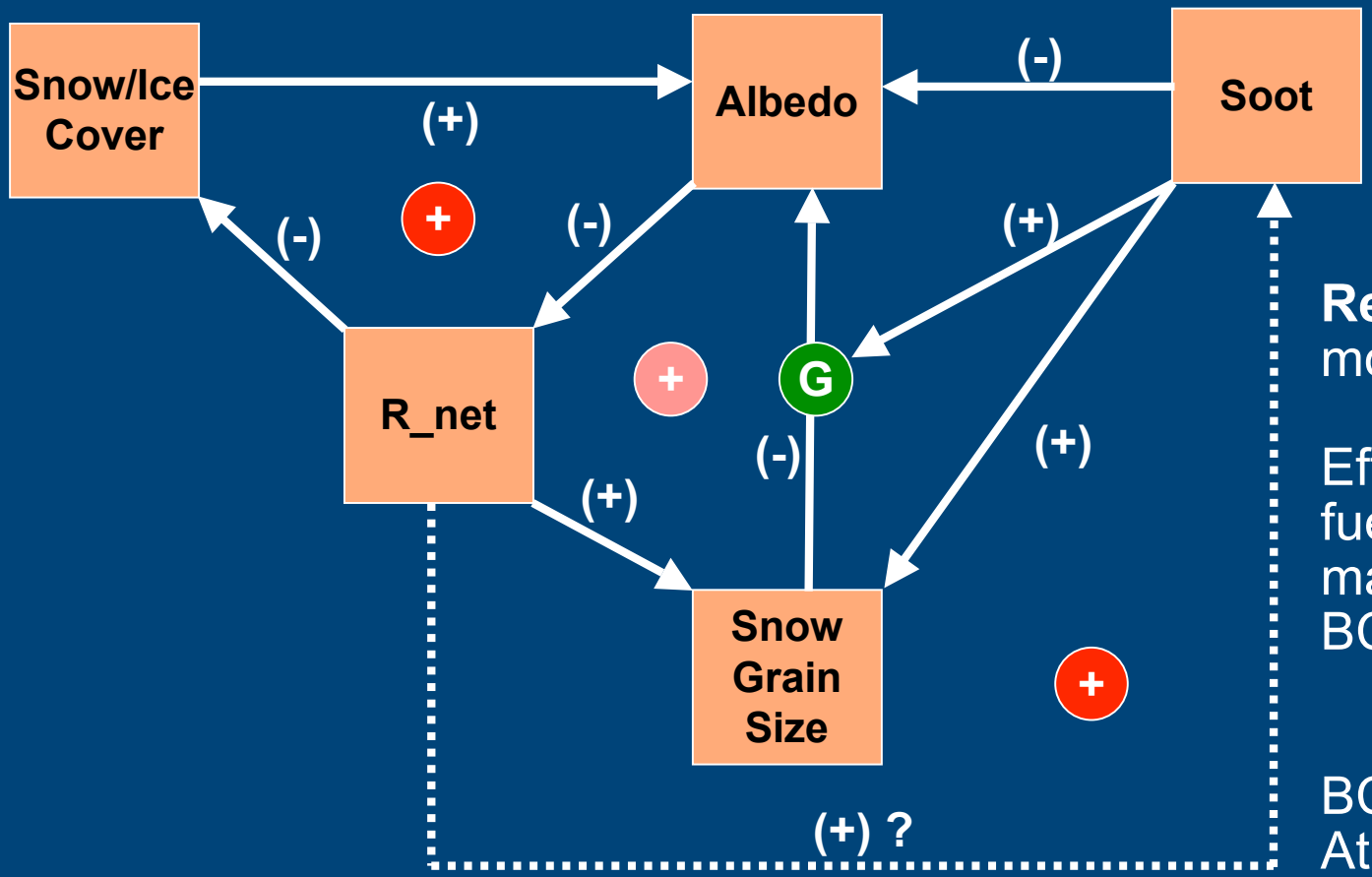
- Multiple positive feedbacks enable very high forcing “efficacy.”
- Large uncertainty in BC emissions, **snow aging**, aerosol removal from snowpack, atmospheric particle transformation.
- Measurements of BC in snow are sparse in space and time.

Black Carbon in Snow: Importance of Snow Aging



- The reduction in albedo caused by a given mass of BC varies three-fold, depending on snow effective grain size.

Black Carbon in Snow: Multiple Positive Feedbacks



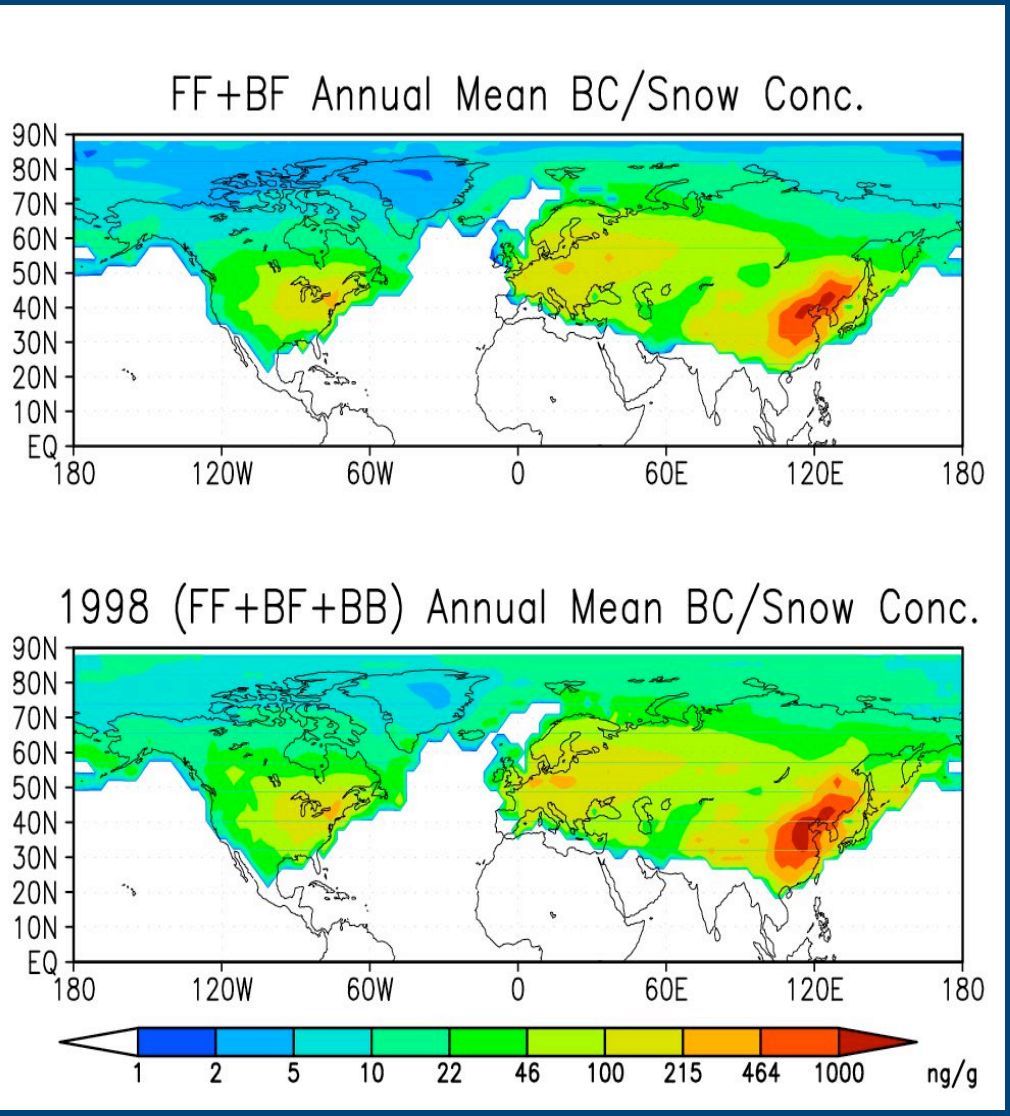
Result: Forcing "Efficacy" more than 3x CO_2.

Effective BC/snow fossil fuel+biofuel forcing has s magnitude as atmospheri BC+OC forcing:

	Fi	F
BC/snow:	+0.04	+
Atm BC+OC:	+0.19	+
	(W/m^2)	

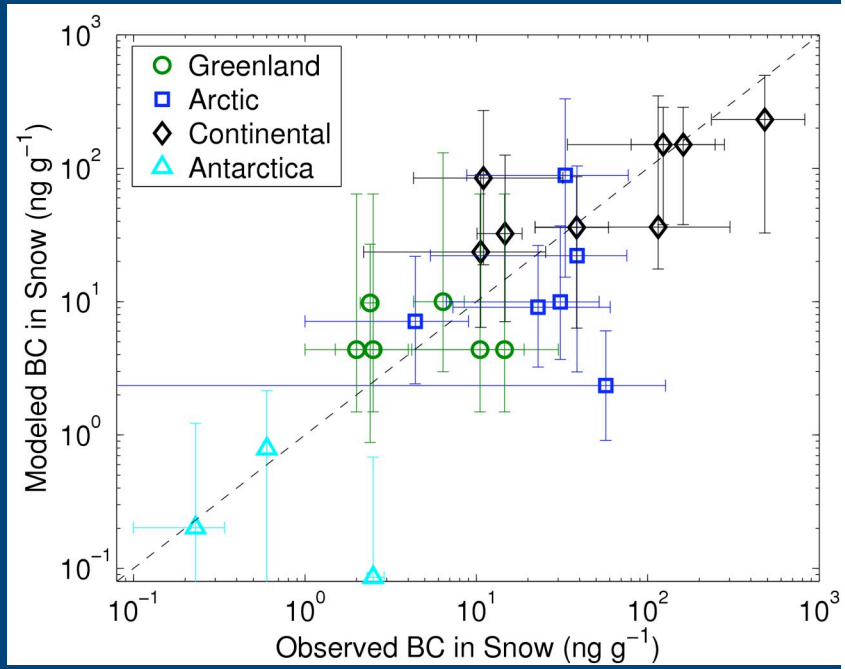
Concentration of hydrophobic and large impurities at the surface during melting**?**

Modeled BC Concentrations in Surface Snow

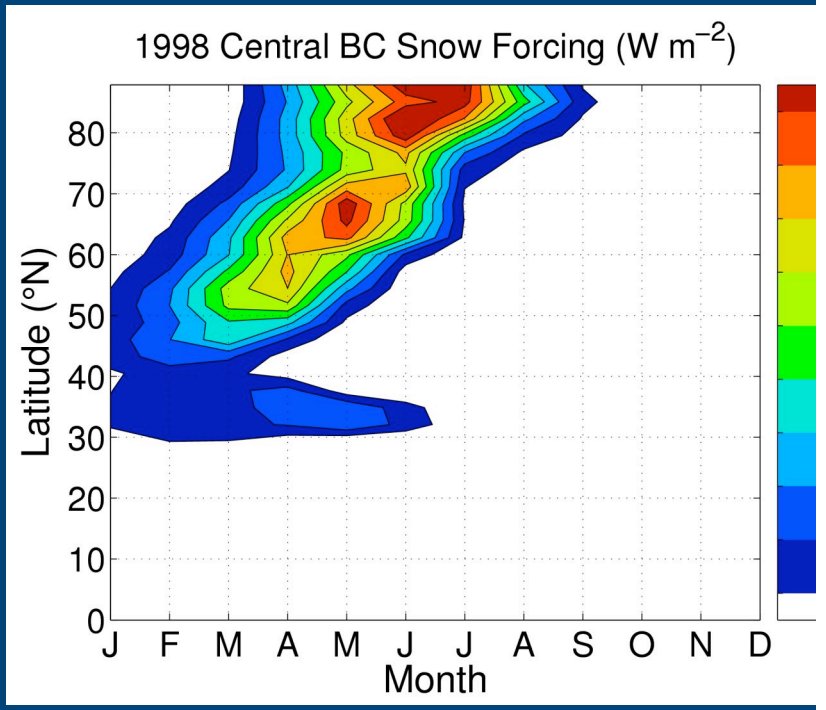


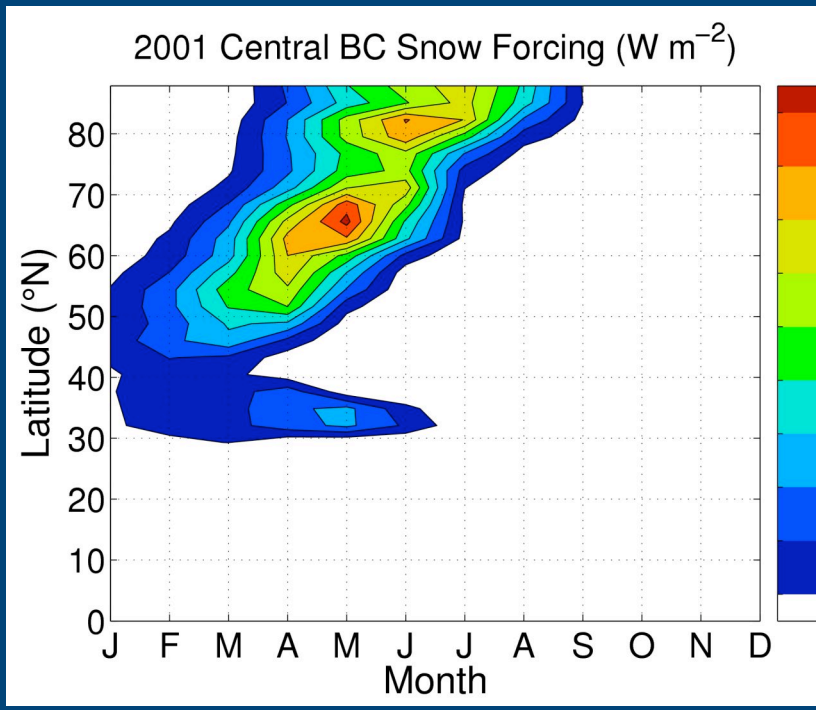
Fossil fuel sources dominate, bu boreal forest fires can contribute up to half of Arctic BC in snow during a strong fire year.

Boreal fire intensity and frequency expected to increase in a warming climate.



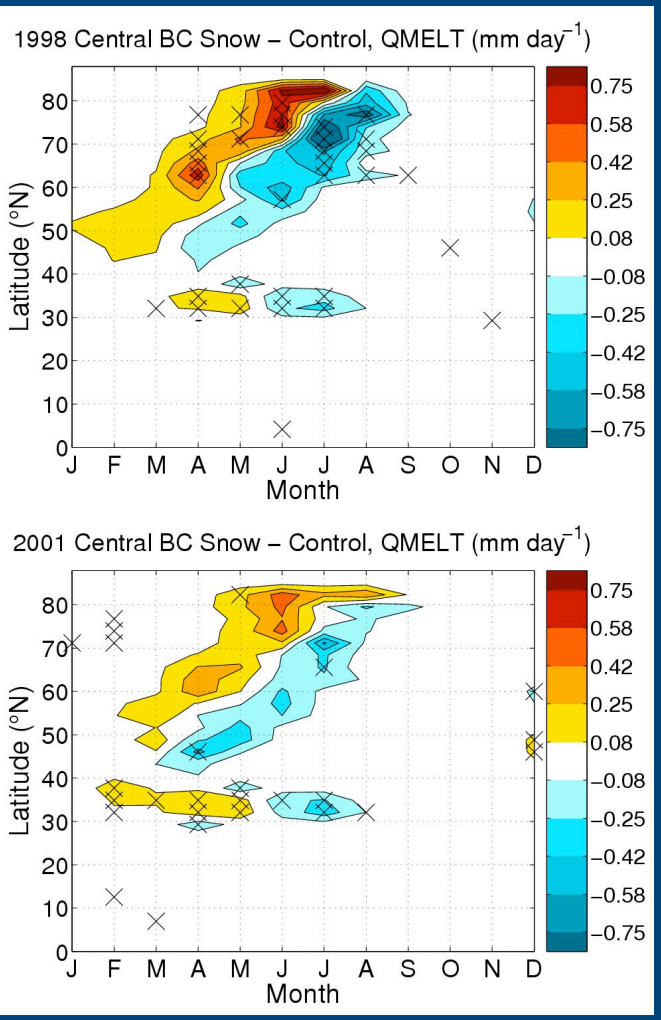
Forcing operates mostly in local springtime, when and where there is large snow cover exposed to intense insolation, coincidentally with peak snowmelt.



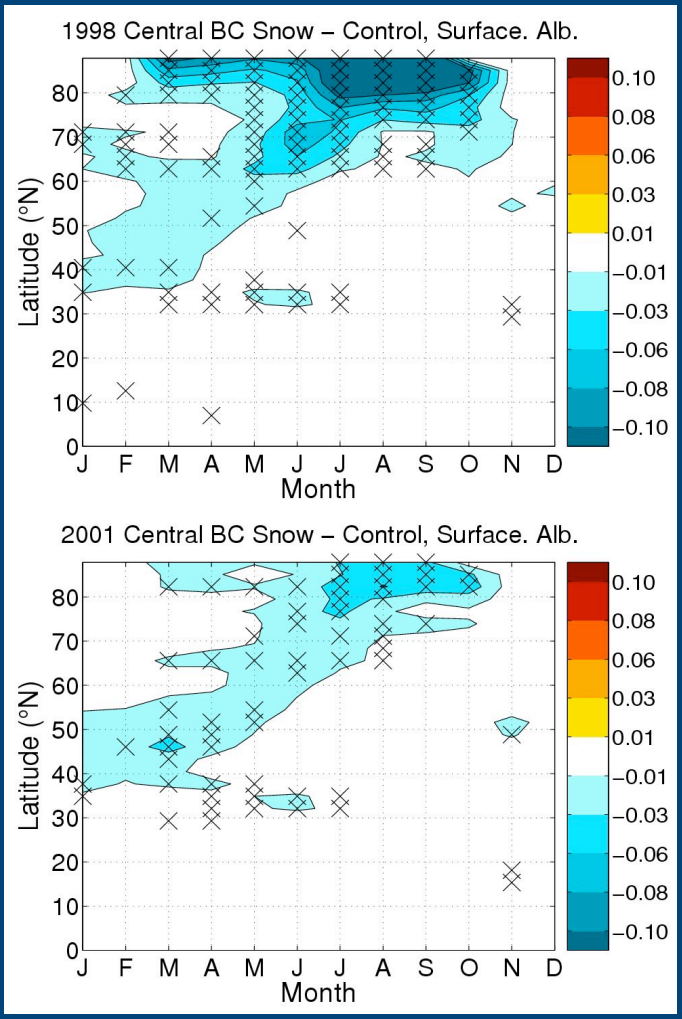


This Forcing...

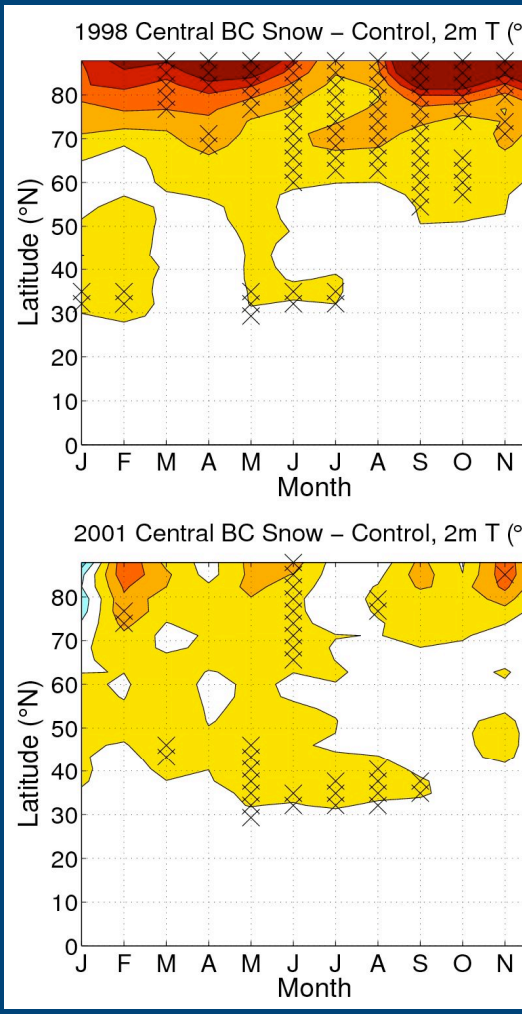
shifts snowmelt earlier



reduces surface albedo



and warms surface



Uncertainties

	Range in Global Forcing (Scalar)
1) BC Emissions	0.54 – 2.00
2) Snow Aging	0.58 – 1.58
3) Melt Scavenging	0.69 – 1.08
4) BC Optical Properties	0.88 – 1.12
5) Snow Cover Fraction	0.83 – 1.08

Methods

- SNow, ICe, and Aerosol Radiative Model (SNICAR), coupled to the NCAR CAM3 GCM with prognostic carbon aerosol transport and deposition [*Rasch et al.*, 2001].
  - SNICAR is two-stream, multi-layer RT model based on *Wiscombe and Warren* [1980] and *Toon et al.* [1989], utilizing Mie parameters computed for a wid range of r_e, which is predicted with dry snow aging model from *Flanner and Zender* [2006].
- 1996 fossil fuel+biofuel BC emissions from *Bond* [200
- Satellite-derived biomass burning BC emissions from Global Fire Emissions Database, v2 [*Van der Werf et* 2006, *Andreae and Merle*t, 2001], constrained with CO inversion factors from *P. Kasibahtla*.
- BC optical properties from *Bond and Bergstrom* [2006